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The Relationship Between the WISC-IV PRI and the Executive Functioning Scale of the BASC-2 in Children Referred for Psychoeducational Assessment

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ABSTRACT

This study addressed the question of whether the Perceptual Reasoning Index (PRI) of the Wecshler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) is a measure of fluid reasoning by correlating the PRI and the Executive Functioning Scale of the Behavior Assesment System for Children-Second Edition (BASC-2; Reynolds & Kamphaus, 1998) in a referred sample. Participants comprised 152 children (109 boys, 43 girls) ranging in age from 6 to 16 years. They were drawn from an anonymous archival database of 931 children who were referred for psychoeducational assessment due to persistent academic concerns, behavioral concerns, or both. Because this was a clinical sample, a check was performed using principal factor analysis to insure the factor structure was the same as that of the WISC-IV standardization sample, which was found to be the case. Also in keeping with the WISC-IV standardization sample, the subtests of the PRI correlated most with one another, although Picture Concepts had a relatively weaker correlation with the PRI compared to the correlation between Picture Concepts and PRI in the normative sample. No significant correlations were found between the PRI and the BASC-2 Executive Functioning Scale, suggesting little to no relationship. A significant correlation was found between the Executive Functioning Scale of the BASC-2 and the Processing Speed Index (PSI). This study did not provide support for the hypothesis that the PRI is primarily a measure of fluid reasoning. Studies that look at the relationship between the PRI and other higher-order cognitive tests, in the context of a comprehensive neuropsychological battery, would be a useful direction for future research.

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CHAPTER I

INTRODUCTION

This study focused on the most common test used to measure intelligence (i.e., the Wechsler Intelligence Scale for Children, WISC) and, specifically, the changes in the latest edition of the WISC to the Perceptual Reasoning Index (PRI). Although the authors state the PRI has made a dramatic shift towards measuring fluid reasoning (Wechsler, 2003a), few studies have provided external validation of this Index. If the PRI is primarily a measure of fluid reasoning as the authors purport, one would expect a relationship between the PRI and some other independent measure of what is considered to reflect fluid reasoning.

This study examined whether the PRI is primarily a measure of fluid reasoning by examining its relationship to another measure, the Behavior Assessment System for Children-Second Edition (BASC-2) Executive Functioning Scale, which purports to measure behaviors reflective of aspects of executive functioning often associated with fluid reasoning abilities. The relationship between fluid reasoning and executive functioning is discussed in detail later in this paper. The data used in this archival study was collected by psychologists at the Greater Essex County District School Board as part of a comprehensive assessment administered to children referred for academic and/or behavioral reasons.

Rationale for the Current Study

Taking the test publisher's view that the PRI of the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) places greater emphasis on fluid reasoning than the previous editions of the WISC, one would expect a relationship between the PRI and the Executive Functioning Scale of the BASC-2. However, other studies question whether the PRI is primarily a measure of fluid reasoning (Hale, Casey, & Ricciardi, 2008; Keith, Fine, Taub, Reynolds, & Kranzler, 2006). If the PRI is not, in fact, chiefly a measure of fluid reasoning, one would expect that the PRI should not be related to the Executive Functioning Scale of the BASC-2.

It is important to look for consistency among the results of investigations using different statistical methods to determine whether the PRI likely measures fluid reasoning. The process of establishing the construct validity of a measure is an ongoing one. Each time a hypothesis is confirmed, confidence in the construct validity of the measure is enhanced. However, if a hypothesis is not confirmed in a single study, it is not necessarily grounds to conclude that the measure is invalid. Many studies that draw similar conclusions are needed to give weight to a theory in order to make the theory generally accepted.

To determine whether the PRI is likely a measure of fluid reasoning, it is important to establish its construct validity. Construct validity:

> ...is directly concerned with the theoretical relationship of a variable (e.g., a score on some scale) to other variables. It is the extent to which a measure "behaves" the way the construct it purports to measure should behave with regard to established measures of other constructs (DeVellis, 2003, p. 53).

For example, if fluid reasoning and executive functioning are conceptually similar (discussed below), the PRI would have construct validity if it correlated significantly with an established measurement of executive functioning. One such well researched measure is the BASC-2, whose Executive Functioning Scale consists of behavioral items that are strongly associated with frontal lobe functioning (Barringer & Reynolds, 1995; Reynolds & Kamphaus, 2002). Further, one might question the construct validity of a measure of fluid reasoning that correlated too highly (e.g., $\geq .45$) with a conceptually unrelated measure.

There are many methods with which to examine construct validity. Two methods used to examine construct validity are convergent and discriminant validity. For convergent validity, a measure should correlate moderately (e.g., $r > .30$ to $r < .4$) with an independent measure reflecting the same or similar constructs. For example, the PRI should correlate with similar items on a different scale, such as the subtests that make up the PRI and the BASC-2 Executive Functioning Scale. Discriminant validity is another type of construct validity where a measure should not correlate significantly with measures of distinctly different constructs.

CHAPTER II

REVIEW OF THE LITERATURE

In this section a review of theoretical and empirically examined concepts is presented, as they relate to the primary focus of the present investigation. This includes the development of the WISC-IV Perceptual Reasoning Index in the context of the Catell-Horn-Catell theory of intelligence and factor analytical methodology, as well as the nature of fluid reasoning/intelligence and its relationship to attentional control and to the general concept of executive functioning. A review of literature related to the role of specific neuroanatomical and neurobehavioral substrates common to executive functioning and fluid reasoning is also included as supportive of the use of behavioral measures of the former to estimate the latter.

Intelligence and *g*

Intelligence has been defined in many ways. For example, Wechsler (1975) defined intelligence as the ability to interpret and meet the demands of the world. Intelligence has also been described as aptitude for abstract reasoning (Saggino, Perfetti, Spitoni & Galati, 2006). In terms of a psychometric definition, Spearman (1904) characterized intelligence as the propensity toward positive correlation of all human abilities. When he examined the results of different tests, Spearman found that there was a positive correlation between the tests for a given individual. In other words, if a certain person performed well on a test of verbal abilities, then that same person also performed well on another test of another cognitive ability, for instance, a mathematics test. Spearman thought the correlation between various abilities was due to general intelligence (*g*), where *g* is a general ability common to all tasks. Spearman used factor analysis to uncover *g* and hypothesized that the *g* factor underlies all problem solving capacities.

Wechsler's View of Intelligence

Wechsler defined intelligence as the collective capacity "of the individual to act purposefully, to think rationally, and to deal effectively with his environment" (Wechsler, 1944, p. 3). One of his earliest intelligence tests, the Wechsler-Bellevue Intelligence Scale – Form I, was based on a global nature of intelligence akin to *g*. That is, Wechsler believed that, "Intelligence is the overall capacity of the individual to understand and cope with the world around him" (p. 5). This scale was the forerunner of the current Wechsler Scales: the WISC-IV, the Wechsler Preschool and Primary Scale of Intelligence - Revised (WPPSI-III), and the Wechsler Adult Intelligence Scale - Fourth Edition (WAIS-IV; Kamphaus, 2001; Kaplan & Saccuzzo, 2001; Sattler, 2001).

While the Wechsler intelligence scales have traditionally measured multiple cognitive domains that are considered to contribute to intelligence, as a whole, beginning with the first edition of the WISC through to the WISC-III, the Wechsler scales have been the subject of longstanding criticisms regarding the scales' insufficient theoretical foundation and the abundance of literature espousing the role of fluid reasoning, working memory, and processing speed in the conceptualization of intelligence (Baron, 2005; Carroll, 1993, 1997; Cattell & Horn, 1978; Wechsler, 2003a). Due to the scale's alleged atheoretical foundation, significant changes were made to the instrument, including the addition of several new subtests (Baron, 2005; Carroll, 1993, 1997; Cattell & Horn, 1978: Wechsler, 2003a). Thus, compared to its predecessors, the WISC-IV ostensibly reflects a more modern approach to intellectual assessment by taking into account contemporary psychometric theories and neurocognitive models of information processing (Kain, 2006; Williams, Weiss, & Rolfhus, 2003).

Factor Analysis of Human Abilities

The most influential theory responsible for many of the revisions to the WISC-IV is the *Cattell-Horn-Carroll Theory of Intelligence (CHC)*. Cattell and Horn favored a factor analytic approach to intelligence in their early research. The detailed description of the psychometric "table of human cognitive elements" in Carroll's (1993) *Human cognitive abilities: A survey of factor- analytic studies*, which concluded that the Cattell-Horn fluid and crystallized intelligence (*Gf-Gc)* theory was the most empirically grounded available psychometric theory of intelligence, lead to McGrew's (1997) recommendation that "all scholars, test developers, and users of intelligence tests need to become familiar with Carroll's treatise on the factors of human abilities" (p. 151). It was further suggested that practitioners observe Carroll's suggestion to "use his 'map' of known cognitive abilities to guide their selection and interpretation of tests in intelligence batteries" (McGrew, 1997, p. 151). Carroll's (1993) work helped bridge the gap between the theoretical and empirical research on the factors of intelligence and the development and interpretation of psychoeducational assessment batteries (McGrew, 1997, p. 151).

The *Cattell-Horn-Carroll (CHC)* theory of intelligence is a marriage between the two most prominent psychometric theoretical models of human cognitive abilities (Daniel, 1997; Snow, 1998; Sternberg & Kaufman, 1998). CHC theory represents the integration of the Cattell-Horn *Gf-Gc* theory (Horn & Noll, 1977) and Carroll's three-stratum theory (Carroll, 1993, 1997). CHC is a psychometric theory in that it is primarily based on procedures that assume that "the structure of intelligence can be discovered by analyzing the interrelationship of scores on mental ability tests. To develop these models, large numbers of people are given many types of mental problems. The statistical technique of factor analysis is then applied to the test scores to identify the 'factors' or latent sources of individual differences in intelligence" (Davidson & Downing, 2000, p. 37).

The psychometric study of cognitive abilities is more than the exploratory factor analysis of a set of cognitive variables. Contemporary psychometric approaches differ from traditional psychometric approaches in three major ways: (1) a greater use of confirmatory (vs. exploratory) factor analysis methods, (2) the structural analysis of items is now as important as the structural analysis of variables, and (3) item response theory models now play a pivotal role (Embretson & McCollam, 2000). While there tends to be a focus only on the factor analytic portions of the contemporary psychometric approach, it is also important to note that non-factor analytic evidence, in the form of heritability studies as well as neurocognitive, developmental, and outcome prediction (occupational and educational) studies, provide additional sources of validity evidence for CHC theory (Horn, 1998; Horn & Noll, 1997). Horn's 1985 *Gf-Gc* conference presentation resulted in Woodcock's decision to consider the multiple ability *Gf-Gc* theory as the model for a revision of the 1977 Woodcock-Johnson Psychoeducational Battery (Schrank, Flanagan, Woodcock, & Mascolo, 2002; Woodcock & Johnson, 1978). Thus, CHC theory was introduced into the field of applied intelligence testing.

Gf-Gc theory received its original name because early versions (Cattell, 1943, 1963) of the theory only proposed two abilities or factors; fluid (*Gf*) and crystallized (*Gc*) intelligence. By 1991, Horn (1991) had already extended the *Gf-Gc* model of Cattell to the identification of nine to 10 broad *Gf-Gc* abilities: Fluid Intelligence (*Gf*), Crystallized Intelligence (*Gc*), Short-Term Acquisition and Retrieval (SAR or *Gsm*), Visual Intelligence (*Gv*), Auditory Intelligence (*Ga*), Long-Term Storage and Retrieval (TSR or *Glr*), Cognitive

Processing Speed (*Gs*), Correct Decision Speed (CDS), and Quantitative Knowledge (*Gq*). The relatively new ability associated with the comprehension and expression of reading and writing skills (*Grw*) was added during this time period (Horn, 1988; McGrew, Werder, & Woodcock, 1991; Woodcock, 1994)

Later, Carroll summarized a review and re-analysis of more than 460 different data sets that included nearly all the more important and classic factor analytic studies of human cognitive abilities. Carroll proposed a three-tier model of human cognitive abilities that differentiated abilities as a function of breadth. At the broadest level (stratum III) is a *general* intelligence factor conceptually similar to Spearman's *g*. Next in scope are eight *broad* abilities that represent "basic constitutional and long-standing characteristics of individuals that can govern or influence a great variety of behaviors in a given domain" (Carroll, 1993, p. 634). Stratum level II includes the abilities of Fluid Intelligence (*Gf*), Crystallized Intelligence (*Gc*), General Memory and Learning (*Gy*), Broad Visual Perception (*Gv*), Broad Auditory Perception (*Ga*), Broad Retrieval Ability (*Glr*), Broad Cognitive Speediness (*Gs*), and Reaction Time/Decision Speed *(Gt*). Finally, stratum level I includes over 70 *narrow* abilities that are included in the stratum II abilities, which in turn are included in the single stratum III *g* factor.

In summary, the Cattell-Horn-Carroll theory of cognitive abilities is a combination of two similar theories about the content and structure of human cognitive abilities. The first of these two theories is *Gf-Gc* theory (Cattell, 1943; Horn, 1965) and the second is Carroll's (1993) three-stratum theory. CHC theory is the most comprehensive and empirically supported framework available for understanding the structure of human cognitive abilities (Carroll, 1993, p. 9). The descriptive accuracy of this model has been presumed in designing studies spanning the domains of psychology, as well as in designing intelligence assessment tools (Johnson & Gottesman, 2006). Indeed, the authors of the WISC have recently tried to bring the WISC-IV into alignment with CHC theory (Wechsler, 2003a).

The PRI

Based on CHC theory, radical revisions were made to the old Perceptual Organization Index (POI), now labeled the PRI, of the WISC-IV. The PRI comprises three core subtests (Block Design, Picture Concepts, and Matrix Reasoning) and one supplemental subtest (Picture Completion). This composite scale represents a major theoretical and structural departure from the WISC-IV predecessors, with measurement of fluid reasoning abilities now representing the primary area of emphasis (Prifitera, Saklofske, & Weiss, 2005).

The PRI is composed of subtests measuring perceptual reasoning and organization (Wechsler, 2003a, p. 6). The change in nomenclature from Perceptual Organization Index (POI) in the WISC-III to PRI in the WISC-IV reflects the intended increased emphasis on fluid reasoning abilities. Compared to other Indexes, the PRI has undergone the most extensive changes from its predecessor. The construct measured by this composite has changed from primarily (visual) perceptual organization with some fluid reasoning to primarily fluid reasoning with some perceptual organization (Prifitera et al., 2005). The two new subtests that were incorporated into the scale to bolster the representation of fluid reasoning skills were: Picture Concepts (a subtest that involves the identification of pictures with a common characteristic) and Matrix Reasoning (a subtest that involves solving incomplete matrixes). Although Matrix Reasoning and Picture Concepts are considered to tap primarily fluid reasoning, Matrix Reasoning requires an element of perceptual organization

(Prifitera et al., 2005). Picture Concepts may invoke verbal mediation, but there is no demand for a verbal response (Prifitera et al., 2005).

The rationale for the present study is based on a growing body of literature that raises concerns regarding the nature of the PRI (Hale et al., 2008; Keith et al., 2006). In particular, Matrix Reasoning and Picture Concepts subtests were included in the PRI to improve its ability to measure fluid reasoning, thereby strengthening the latent constructs of the PRI (Wechsler, 2003a, p. 9). Despite the heavy weighting of Matrix Reasoning and Picture Concepts on the PRI, little validity data examining these subtests exists. Further, the PRI may also measure visual-spatial processing due to the influence of its third subtest (i.e., Block Design).

Fluid Reasoning

Since the authors of the WISC-IV claim the PRI measures fluid reasoning, an examination of what fluid reasoning consists of is warranted. Fluid reasoning is a psychometric construct based on the results of factor analytic studies (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). Nevertheless, fluid reasoning remains a somewhat ill defined construct, most often referred to as fluid abilities or reasoning abilities associated with frontal lobe functioning (Kane, Hambrick, & Conway, 2005). Many studies have made the assumption of what fluid reasoning is based on what it is not. These assumptions come from looking at fluid reasoning's assumed opposite, crystallized intelligence.

Crystallized intelligence is defined by Sattler (2001) as "a broad pattern of the achievements and knowledge that are emphasized in acculturation" (p. 141). This kind of intelligence involves "overlearned and well established cognitive functions and is related to mental products and achievements." (Sattler, 2001, p. 140). That is, crystallized intelligence relies on school learning and life experience. It is dependent on the culture of the person. *Gc* mainly loads on primary factors as numerical, verbal, and mechanical abilities (Saggino et al., 2006). In the WISC series, crystallized intelligence has traditionally been measured using verbal tasks. It has been put forward that verbal comprehension relies on the individual's response to verbal stimuli and is indicative of the individual's crystallized intelligence (Kaufman & Lichtenberg, 2000).

In contrast, fluid reasoning has been traditionally associated with nonverbal intelligence tasks. Tests of nonverbal intelligence measure comprehension and reasoning presumably using culturally free information that does not require the use of language. Tasks of nonverbal intelligence are ideally solved without requiring the individual to read, write, speak, or listen. They also require little or no dependence on "social or school-learned skills and knowledge" (Kamphaus, 2001). Therefore, since crystallized intelligence relies on previously learned information, it is assumed that fluid reasoning is not significantly dependent on previous knowledge. Hence, fluid reasoning is often assessed through the use of tasks that involve solving novel problems. It is considered the basic reasoning ability (Saggino et al., 2006). *Gf* mainly loads on factors such as intellectual speed, memory span, and induction (Saggino et al., 2006).

In Cattell's (1971) investment theory, fluid ability is conceptualized as a general relation-perceiving ability that is tied to the associational neuronal development of the cortex. Crystallized intelligence is a representation of fluid reasoning previously invested in learning experiences. In two- to-three-year old children, crystallized ability and fluid ability are highly correlated. This correlation declines with age as children become more attuned to culture (Saggino et al., 2006).

Carroll predominantly used two tests that tapped fluid reasoning in the process of devising the Three Stratum Theory, namely Raven's Progressive Matrices and the Culture Fair Intelligence Test. According to Carroll (1993), Raven's Progressive Matrices and the Culture Fair Intelligence Test are types of reasoning tasks that tap induction. Induction tasks require a person to "inspect a set of materials and from this inspection induce a rule governing the materials, or a particular or common characteristic of one or more stimulus materials, such as a relation or trend" (Carroll, 1993, p. 211). This means that people who score high on Raven's Progressive Matrices or the Culture Fair Intelligence Test are able to follow a set of rules to solve the incomplete matrices and other problems that are part of the task. Raven's Progressive Matrices and the Culture Fair Intelligence Test (Matrices subtest) are similar to the Matrix Reasoning subtest of the WISC-IV. However, the Block Design and Picture Concept subtests of the WISC-IV differ from the tests used by Carroll, the first primarily tapping perceptual organization and the second abstract, categorical reasoning. Thus, the PRI may not significantly overlap with Carroll's definition of fluid reasoning, which included the underlying construct of induction.

Still, fluid reasoning is cognitively thought to be related to executive control tasks that involve continuous processing (Carpenter, Just, & Shell, 1990; Deary, 2000; Engle, Kane, & Tuholski, 1999). In behavioral measures, individual differences in fluid reasoning are most obvious when attentional control is needed (Engle, Kane, et al., 1999; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002). For example, Conway et al. (2002) compared multiple measures of short-term memory capacity, attentional control, and processing speed against measures of general fluid reasoning in a sample of 120 young adults. Raven Advanced Progressive Matrices (Raven, 1965) and the Culture Fair Intelligence Test (Cattell

& Cattell, 1959) were used as the fluid reasoning measures. Structural equation modeling was then performed to determine which construct served as the best predictor of general fluid intelligence. The results suggested that attentional control was a good predictor of general fluid intelligence while short-term memory capacity and processing speed were not good predictors of fluid intelligence.

Further, Engle, Tuholski, Laughlin, and Conway (1999) conducted a study in which 133 participants performed 11 memory tasks, two tests of general fluid intelligence, and scholastic aptitude tests. Some of the memory tasks were thought to reflect working memory (e.g., operation span, reading span, counting span) and some were thought to reflect short-term memory (e.g., forward span-dissimilar, forward span-similar, backward span). Structural equation modeling suggested that short-term memory and working memory reflect separate but highly related constructs and that many of the tasks used in the literature as working memory tasks reflect a common construct. Working memory and, in particular, attentional control, showed a strong connection to fluid intelligence, but short-term memory did not. A theory of working memory capacity and general fluid intelligence was proposed. The authors argued that working memory capacity and fluid intelligence reflect the ability to keep a representation active, particularly in the face of interference and distraction. The authors also thought this capability was related to controlled attention and the functions of the prefrontal cortex. Thus, according to the above studies, fluid reasoning and attentional control are considered related (Conway et al., 2002; Engle, Tuholski, et al., 1999).

Neuroimaging studies have found fluid reasoning covaries with neurological activity in areas crucial for attentional control (Gray, Chabris, & Braver, 2003). Moreover, the relationship between fluid reasoning and brain activity is stronger under high-interference conditions than under low-interference conditions (Gray et al., 2003). Anatomically, the neural substrate of fluid reasoning is thought to include portions of the prefrontal cortex (Duncan, Seitz, et al., 2000; Markowitsch & Kessler, 2000; Prabhakaran, Smith, Desmond, Glover, & Gabrielie, 1997; Thompson et al., 2001). An attentional control view suggests that fluid reasoning is related to areas of the brain associated with attentional control, specifically the lateral prefrontal cortex, dorsal anterior cingulate and lateral posterior cerebellum (Braver et al., 1997; Cabeza & Nyber, 2000; Carter et al., 1998; D'Esposito, Postle, Jonides, & Smith, 1999; Gruber, 2001; MacDonald, Cohen, Stenger, & Carter, 2000; Paus, Koski, Caramanos, & Westbury, 1998; Petersen, van Mier, Fiez, & Raichle, 1998; Posner & Petersen, 1990; Schmahmann & Sherman, 1998). Because of its relationship with the frontal lobe, it is thought that fluid reasoning may be dimensional and overlap with executive functioning (Saggino et al., 2006).

Executive Functioning

Executive functioning is a broad and heterogeneous construct that encompasses some very specific behaviors (Baron, 2004). General terms such as problem solving and concept formation are being replaced by more specific terms and operational definitions. However, executive functioning remains an abstract construct that is subject to varying interpretations (Archibald & Kerns, 1999). Executive functioning is an umbrella term that includes a number of subdomains derived from empirical studies. Common executive function subdomains include, but are not limited to: set-shifting, problem solving, abstract reasoning, organization, fluency, inhibition, initiative, mental flexibility, anticipation, behavioral regulation, hypothesis generation, concept formation, planning, goal setting, working memory, self-monitoring, self-control, attentional control, estimation, common sense, and creativity (Baron, 2004).

The proposed definitions of executive functioning vary, yet overlap considerably. There is some uniformity in conceptualizing the overarching construct. For example, it is generally agreed that executive functions are higher functions that integrate more basic abilities such as perception, attention, and memory (Baron, 2004). Executive functioning can be conceptualized as regulatory control (Nigg, 2000) and described as the capacity to engage in independent, purposeful, self-serving behavior (Lezak, 1995). Similarly, executive functions can be thought of as a collection of processes that guide, direct, and manage cognitive, emotional, and behavioral functions, particularly during active, novel, problem solving (Gioia, Isquith, Guy, & Kenworthy, 2000).

In terms of neuroanatomy, adult and primate studies relate executive functioning with the prefrontal cortex (Baron, 2004; Cummings, 1993; DiStefano et al., 2000; Miller, 2000). For example, Cummings (1993) linked dysfunction of prefrontal circuits to disorders of executive function. Further, Miller's (2000) work with monkeys demonstrates that prefrontal neurons also have properties consistent with executive functions. They can select behaviorally relevant information from sensory inputs and from long-term memory, integrate diverse information to serve common behavioral goals, and represent information about behavioral context. The latter property may reflect the role of the prefrontal cortex in representing the abstract rules that guide complex thoughts and actions. In children, the neural substrate underlying executive functioning is not as clearly delineated, but there is evidence of frontal and subcortical contributions as with adults (Baron, 2004; Cummings, 1993).

An essential question is whether any single, unified theory of executive processes can adequately predict the wide range of behaviors associated with the prefrontal lobes. Several prominent theories of working memory and attention have promoted a singular view of executive functions. For example, Norman and Shallice's (1986, 2000) model of attentional control proposes a unitary "supervisory attentional system" biasing the activation of task schemas. This and similar models distinguish between two levels of cognitive functioning: a lower level of routine cognitive skills (e.g., memory and language) and an upper level specifically devoted to control and modulation of enduring cognitive ability.

Norman and Shallice's Model of Attentional Control

While it is beyond the scope of this study to examine the validity of Norman and Shallice's (2000) model of attentional control, this model illustrates the idea of a latent construct that underlies, or is tapped into by, what psychologists measure on executive functioning tasks. Norman and Shallice make the distinction between "willed" acts and automatic control of behavior, where "willed" acts are akin to acts requiring executive functions. According to Norman and Shallice, the tasks that require deliberate attentional resources fit into the following categories: "they involve planning or decision making, they involve components of troubleshooting, they are ill-learned or contain novel sequences of actions, they are judged to be technically difficult, they require the overcoming of a strong habitual response or resisting temptation."

Norman and Shallice (2000) account for the fact that in "normal life" many activities overlap, where it is necessary to prevent conflicts between incompatible actions. They use a threshold model to explain how an action switches from automatic to requiring attentional control. When a schema is selected that exceeds a threshold, it continues to operate unless actively switched off, until it has satisfied a goal or completed its operations, or until it is blocked (e.g., by a more highly activated schema). Then, contention scheduling becomes necessary to prevent simultaneous action of conflicting activities.

Sometimes a schema may not be available to achieve control of a desired behavior, especially when the task is novel or complex. In these cases additional control is required. Norman and Shallice (2000) propose a central executive, which they call the supervisory attentional system, that operates through the application of extra activation and inhibition to schemas in order to bias their selection by the contention scheduling mechanisms. The functions Norman and Shallice assume for the supervisory attentional control/central executive, such as the regulation of goal-directed behavior, correspond closely with those ascribed to prefrontal regions of the brain (Desmond, Gabrieli, & Glover, 1997; Duncan & Owen, 2000), namely, those required for executive functioning. PET studies have shown increased activation in the prefrontal cortex, particularly in the anterior cingulate gyrus during tasks involving internally planned or voluntary actions (Colebatch et al., 1991; Sadato, 1996). Therefore, according to Norman and Shallice's model of attentional control and other overlapping models of executive functioning (e.g., Baddeley, 1986), it is likely there is a latent construct or central executive that is necessary to carry out executive functions and that this construct is dependent on prefrontal regions of the brain.

The Relationship Between Fluid Reasoning and Executive Functioning

Duncan, Burgess, and Emslie (1995) assert that fluid intelligence tasks rely on the integrity of the frontal lobes and may be the best measure of executive functioning. They compared patients with frontal lesions of varying etiologies to control patients with posterior involvement on standard and fluid intelligence tests. Patients with frontal lesions and superior IQs on the Wechsler Adult Intelligence Scale-Revised (WAIS-R) showed impairments of 20–60 points on the Culture Fair Intelligence Test (Cattell & Cattell, 1959), a conventional measure of fluid intelligence or novel problem solving. There was no significant difference between WAIS-R and Culture Fair IQs in posterior patients.

These findings suggest a relationship between fluid intelligence and executive functions. Further, Duncan, Emslie, Williams, Johnson, and Freer (1996) highlight the importance of goal management ability in the relationship between fluid reasoning and executive control. Subjects were asked to follow a specific rule coded by a cue in a complex visual switching task. Neglect of one cue was occasionally apparent in subjects, even though they plainly recalled the rules of the task. It was postulated that the neglected cue was ineffective in terms of controlling behavior. This goal neglect is often found in frontal patients as well as in neurologically intact subjects. It is of note that subjects who more frequently showed goal neglect were the same who obtained low *g* scores on the Culture Fair Intelligence Test. The correlation between *Gf* and goal neglect leads to the hypothesis that both executive and fluid processes deal with a higher-level function concerning abstract action and goal selection under novel conditions.

Another specific cognitive function related to fluid intelligence is working memory. Lohman (2001) suggested that reasoning tasks, such as Raven Advanced Progressive Matrices (Raven, 1965), burden the management of attentional resources in working memory, as they involve simultaneous retention and manipulation information. In particular, fluid intelligence could be classified as "inductive reasoning" exemplified by the ability to remember, transform, and organize information: these three abilities would be classified under control of working memory, where *Gf* and working memory would be considered as part of the same construct.

Carpenter et al. (1990) showed the significance of working memory and goal management in solving Raven Advanced Progressive Matrices. They first considered the items that make up the Raven and then parsed out the various mental processes implicated in the performance. They found two individual types of problems (figural and analytic), and highlighted five kinds of rules that enabled the subject to reach the correct answer. The type of problem (figural versus analytic) and quantity of rules determined the complexity of the task. The authors analyzed detailed performance characteristics, such as verbal protocols, eye-fixation patterns, and errors, and then individuated the processes distinguishing between high- and low-scoring subjects. The most important individual differences in solving the Raven test derived from the ability to induce abstract relations and the ability to dynamically manage a large set of problem-solving goals in working memory. In other words, the authors highlighted the important contribution of working memory and goal management in solving a highly *Gf* representative test (Snow, Killonen, & Marshallek, 1984).

Studies on normal aging provide further support for the hypothesis of a relationship between executive functioning and fluid reasoning. It is well established that frontal lobes deteriorate earlier and more severely than other brain areas as part of normal aging (Haug et al., 1983). This frontal deterioration may be the substrate of age-related cognitive impairments (Daigneault & Braun, 1993; Moscovitch & Winocur, 1995; West, Ergis, Winocur, & Saint-Cyr, 1998) in many tests commonly used to assess executive functions, such as letter fluency (Phillips, Gillholy, Logie, Della Sala, & Winn, 1996; Whelian & Lesher, 1985), the Stroop test (Boone, Miller, Lessere, Hill, & D'Elia, 1990) and the WCST

(Daigneault, Braun, & Whitaker, 1992). Whereas some of these tasks may be confounded by processing speed, research on tasks of categorization show that performance on untimed tasks decline with normal aging (Daigneault, Braun, & Whitaker, 1992: Fera, 2006). Similarly, age-related deficits in completing intelligence tests were found. Phillips and Della Sala (1998) reviewed the first study demonstrating age-related attrition of abstract reasoning abilities, that of Yerkes (1921). From that time forward, numerous studies have shown the changes in intelligence and problem-solving can be explained in terms of localized changes in the frontal lobes of the brain (Saggino et al., 2006). Given this, and in keeping with Cattell's theory of fluid versus crystallized intelligence, it appears age differences on intelligence tests may relate to a decline in *Gf* (Allamanno, Della Sala, Laicona, Pasetti, & Spinnler, 1987, Duncan et al., 1995, Haug et al., 1983).

In terms of neuroimaging and neurophysiological studies, several researchers have found that the prefrontal cortex subsumes processes similar to those characteristic of *Gf* and executive functioning. Desmond, Gabrieli, and Glover (1997) used functional magnetic resonance imaging (fMRI) while subjects solved three different types of problems (figural, analytic, and match) taken and adapted from the Raven Advanced Progressive Matrices and the Raven Standard Progressive Matrices (Raven, Raven, & Court, 2003). The figural items required mostly visual-spatial analysis to determine the correct answer, while the analytic required more abstract reasoning. Match problems were considered as the control task and required matching identical figures. Fluid reasoning produced fMRI activation of a vast, but precise, system of cortical regions, including areas occupied in domain-dependent and domain-independent working memory systems. Specifically, figural reasoning activated regions mediating working memory for spatial and object information and for mental imagery (middle frontal gyrus, inferior and superior parietal regions, inferior and middle temporal gyrus, predominantly situated in temporal regions of the right hemisphere). During analytic reasoning, in addition to the same right frontal activation was activation in the left frontal region along the inferior and middle frontal gyrus and in premotor cortex. The involvement of these regions in verbal and semantic working memory has been demonstrated, illustrating deep associations of different domain dependent working memory systems in fluid and figural reasoning. An important question is whether there is an identifiable cortical network which coordinates and directs all these systems. The authors revealed a pattern of activation in the dorsolateral and rostrolateral prefrontal areas exclusively in the analytic condition. They suggested that these regions contribute to a domain-independent working memory system that plays the role of executive control on other higher-order processes. It is likely these areas are also involved in the active maintenance of relevant task information, separate from the nature of the stimuli (e.g., verbal, spatial, semantic).

Other neuroimaging studies support this hypothesis. Duncan and Owen (2000) reviewed 20 distinct functional imaging studies with different cognitive task demands (including aspects of perception, response selection, executive control, working memory, episodic memory, and problem solving) examining specific cortical activations common to the studies. They showed clusters of activation from very different studies in the same frontal and parietal regions. On the lateral surface of both hemispheres, two prominent clusters were discovered around the posterior part of the anterior cingulate and the adjacent supplementary motor area. Thus, it is apparent that a specific frontal-lobe network is consistently recruited for solution of diverse cognitive problems, supporting the subsistence of a unique factor. This unique factor may be related to *Gf*. In a PET study, Duncan, Seitz, et al. (2000) analyzed brain activation during spatial, verbal, and perceptuo-motor tasks with high-*g* involvement as compared to low-*g* control tasks. For example, participants were exposed to spatial, verbal, and perceptuo-motor tasks, where each task item consisted of four display elements (drawings or letter sets), and the aim was to identify the element that in some sense mismatched or differed from the others. Materials for the high-*g* spatial task were adapted from the Culture Fair Intelligence Test (Cattell & Cattell, 1959). Display elements were four panels, each containing one or more shapes, symbols, or drawings. One panel differed in some respect from the others; extensive problem solving was required to identify this panel because the difference could concern any property, often abstract and/or complex. In the low-g spatial control task, in contrast, there was minimal problem solving. In each display, the four panels each contained a single geometrical shape, three of which were physically identical whereas the fourth differed in some visually obvious respect (shape, texture, size, orientation, or a combination of these). A similar process was used for the high-*g* versus low-*g* verbal and perceptuo-motor tasks. The results showed a specific recruitment, for the high-*g* loaded task, of the lateral frontal cortex in one or both hemispheres, which resembles the frontal areas individuated by Duncan, Seitz, et al. in their review paper. The results suggest that fluid intelligence derives from a specific frontal system important in the control of diverse forms of behavior.

This purported supervisory role of the lateral prefrontal cortex is also supported by an fMRI study by Gray et al. (2003). This study used an individual-differences approach to test whether *Gf* is mediated by brain regions that support attentional (executive) control, including subregions of the prefrontal cortex. Forty-eight participants first completed a standard measure of *Gf* (Raven's Advanced Progressive Matrices). They then performed verbal and nonverbal versions of a challenging working-memory task (three-back) while their brain activity was measured using fMRI. In the three-back task, participants viewed a series of stimuli that were either all words or faces, with a new stimulus appearing every 2.36 seconds. The participants were asked to indicate as quickly and accurately as possible whether the new stimulus matched or did not match the stimulus seen three items previously, using two response buttons. Trials within the three-back task varied greatly in the demand for attentional control because of differences in trial-to-trial interference. On high interference trials specifically, where a correct answer necessitates high executive control, participants with higher *Gf* were more accurate and had greater interference event-related neural activity in several brain regions. These data suggest a very specific connection between fluid intelligence and executive functions. Multiple regression analyses indicated that lateral prefrontal and parietal regions may mediate the relation between ability (*Gf*) and executive performance.

Thus, neuroimaging studies clearly show that prefrontal cortex, and a specific prefrontal-parietal network, is involved in many different cognitive processes, and that their functioning is specifically related with *Gf*. It has been posited that these regions comprise a domain-independent working memory system that serves to provide executive control over other higher order cognitive processes. Further, it has been postulated that executive functioning depends on fluid intelligence (Duncan et al., 1995) and that fluid intelligence is an important contributor to executive functioning across multiple executive functioning measures (Zook, Davalos, DeLosh, & Davis, 2004).

From the above review, it can be concluded that executive functions and fluid reasoning are often described in similar ways and with similar properties. Research suggests they share neuroanatomical and neurobehavioral substrates. Therefore, it appears that fluid reasoning and executive functions involve many of the same or similar cognitive constructs.

The concepts of fluid reasoning and executive functioning have differing origins. While fluid reasoning was mathematically developed, the concept of executive functions was introduced by neuropsychology to account for a wide range of symptoms presented by frontal lobe patients. It seems these two different approaches led to different definitions and different descriptions of similar underlying processes. Studies of normal aging have documented well the association of the *Gf* attrition to the decline of the frontal lobe (e.g., Haug et al., 1983). The same pattern happens with the executive functions (e.g., Allamanno et al., 1987). The correlation between *Gf* and goal neglect in neuroanatomically typical subjects contribute further proof to this hypothesis (Duncan et al., 1995). Both executive and fluid processes seem to deal with a higher-level function concerning goal selection and abstract action under novel conditions.

Many neuroimaging, neurophysiological, and behavioral studies, as reviewed above, seem to intersect on the proposal that a strong association between *Gf* and executive functioning does exist, and that it mirrors executive control processes and prefrontal functioning. Finally, neuropsychological data connect executive control, goal management, *Gf* scores, and the disorganization of intelligent behavior following frontal lesions. Using this rationale, one could hypothesize that poor executive functioning manifests as poor performance on fluid reasoning tasks and vice versa. As such, it is reasonable to expect that behavioral measures of executive functioning should be related to cognitive measures of fluid reasoning.

Factor Analyses of the WISC-IV

Since fluid reasoning can be conceptualized as a construct developed from factor analytic studies, it makes sense to look at the factor analyses studies of the WISC-IV to examine the latent constructs of the PRI. Keith et al. (2006) used CHC theory to examine the WISC-IV standardization sample, which puts forward that Matrix Reasoning and Picture Concepts rely on inductive reasoning, chief components of fluid reasoning. Keith et al. also assumed that quantitative skills are subsumed by fluid reasoning and, thus, placed Arithmetic in the fluid reasoning factor as well. This study split Perceptual Reasoning tests into two factors: fluid reasoning and visual processing. The results of the confirmatory factor analysis in this study showed that their CHC model was a better fit than the WISC-IV model.

Keith et al. (2006) also ran a series of analyses allowing Arithmetic to load on the fluid reasoning, short-term memory, and crystallized intelligence factors. These analyses suggested that the Arithmetic subtest measures a convoluted blend of abilities including fluid reasoning, short-term memory, and verbal comprehension and knowledge. The authors questioned, given the loadings of Arithmetic on three factors, whether it is worth placing Arithmetic in a separate factor. However, as Arithmetic loaded primarily on the fluid reasoning factor, their findings suggested that Arithmetic measures primarily fluid reasoning. The authors also suggested that when Picture Concepts, Arithmetic, and Matrix Reasoning are inconsistent, Arithmetic may be a reflection of short-term/working memory or crystallized intelligence. Further, Keith et al. calculated the loadings of each subtest on the *g* factor. Arithmetic had the highest loading on *g* (0.79), followed by Vocabulary (0.75).

Keith et al.'s (2006) final confirmatory factor-analytic model found a five-factor model better suited the WISC-IV normative data. These five factors were as follows: 1) crystallized intelligence, 2) visual processing, 3) fluid reasoning, 4) short-term memory, and 5) processing speed. While the crystallized intelligence factor contains the same subtests as the Verbal Comprehension Index (VCI) and the short-term memory factor contains the same subtests as the Processing Speed Index (PSI), the other three factors differ from the WISC-IV factors (see Table 1). Keith et al. suggest that children who experience difficulty with visual processing may be less impaired in the area of fluid reasoning. Most importantly, this study raises the question whether the PRI is a good measure of fluid reasoning as suggested by the authors of the WISC-IV (Wechsler, 2003a) or whether it is measuring a convoluted blend of abilities including fluid reasoning as well as visual processing.

Table 1

WISC-IV Versus CHC Factors

WISC-IV Subtest	WISC-IV Index	CHC Factor
Block Design (BD)	Perceptual Reasoning	Visual Processing
Picture Concepts (PCn)	Perceptual Reasoning	Fluid Intelligence
Matrix Reasoning (MR)	Perceptual Reasoning	Fluid Intelligence
Picture Completion (PCm)	Perceptual Reasoning	Visual Processing
Digit Span (DS)	Working Memory	Short-Term Memory
Letter-Number (LN)	Working Memory	Short-Term Memory
Arithmetic (AR)	Working Memory	Fluid Intelligence

In a study of 291 children referred for psychoeducational assessment, a sample that partly overlapped with the current study, Hale et al. (2008) used cluster analysis to identify cognitive subtypes of WISC-IV subtest patterns. The empirically-defined subtypes included:

Low Verbal Comprehension (LV), Low Verbal Comprehension and Working Memory (LVWM), Low Perceptual Reasoning and Processing Speed with Average Picture Concepts (LPRPS), Low Digit Span and Coding (LDC), and Low Ability (LA). The profile associated with one cluster, LPRPS, was complicated as Picture Concepts did not vary with the other subtests on the PRI. Specifically, Block Design and Matrix Reasoning were below average, whereas Picture Concepts was found to be in the average range, representing the highest score in that profile. This study raises questions regarding the construct(s) measured by the Picture Concepts subtest and the PRI in general given the prominent role that Picture Concepts is considered to play in the PRI. One possible explanation is that children are using verbal mediation to problem solve when formulating their responses on the Picture Concepts subtest (Wechsler, 2003a, p. 50). In the WISC-IV standardization data, Picture Concepts loads on the Verbal Comprehension Index (.21 versus .20 on the PRI) in younger children (6-7 years old), suggesting verbal mediation (Wechsler, 2003a). In a clustering study using the WISC-III, similar to that of Hale et al. (2008), Waxman and Casey (2006) identified a subtype characterized by deficits in visual processing speed within the context of an elevated Picture Completion score. The Picture Completion subtest is also considered highly susceptible to verbal mediation (Wechsler, 2003a).

Yeates and Donders (2005) predicted that the PRI may show less sensitivity to brain dysfunction than did either the POI or the PIQ, possibly because of the reduced reliance on motor skills and speed, two areas of deficit commonly seen in children with neurological conditions. Children with traumatic brain injury (TBI) displayed deficits on the PRI in the clinical validity study presented in the WISC-IV manual (Wecshler, 2003a), but differences among its constituent subtests were significant only for the Block Design and Picture

Completion subtests, and not for Picture Concepts or Matrix Reasoning. Another study by Donders and Janke (2007) found that the PRI does not distinguish between children with TBI and demographically matched healthy controls. A study conducted by Allen Thaler, Donohue and Mayfield (2010) also concluded that the PRI is not sensitive to brain injury. The results of these studies are concerning, as tests of executive functioning and fluid reasoning are typically highly sensitive to such neurological conditions.

These studies point to the need for validation of the PRI to help professionals interpret WISC-IV findings. As previously stated, if the PRI is primarily a measure of fluid reasoning, then there should be some relationship between the PRI and another measure of something akin to fluid intelligence, such as the Executive Functioning Scale of the BASC-2.

The BASC-2

One way of measuring executive functioning is through ratings of a child's behavior on dimensions that may be reflective of aspects of executive functioning, fluid reasoning, planfulness, and attentional control. The BASC-2 is a well-researched behavioral measure that taps, among other things, executive functioning. The BASC-2 is preferred by many researchers and clinicians over other behavioral measures for numerous reasons. For instance, the BASC-2 has a short administration time (10-20 minutes); T-scores and percentiles are provided for the general population as well as clinical populations; scores can be interpreted based on the child's gender or based on genders combined scores; it covers a wide age range, from 2:0 through 21:11. Further, the BASC-2 uses a multidimensional approach for conducting a comprehensive assessment. It has a strong base of theory and research which give a thorough set of highly interpretable scales (Reynolds & Kamphaus, 1992, 1998). It is ideally suited for use in identifying behavior problems as required by the

Individuals with Disabilities Education Act (IDEA), and for developing Functional Behavior Assesments, Behavioral Intervention Plans, and Individualized Education Plans (Reynolds & Kamphaus, 1992, 1998). Norms are based on current census population characteristics. Also, the BASC-2 is efficient at differentiating between hyperactivity and attention problems (Reynolds & Kamphaus, 1992, 1998).

The BASC holds an exceptional track record for providing a complete picture of a child's behavior (Reynolds & Kamphaus, 1992, 1998). School and clinical psychologists have used the BASC clinically for over a decade. Based on an electronic literature review, using BASC as the key term, it has been used in over 245 research studies. It provides the most comprehensive set of rating scales (Reynolds & Kamphaus, 1992, 1998). These scales measure areas important for both IDEA and Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) classifications. In addition, the BASC-2 is respected for its developmental sensitivity. It provides the most extensive view of adaptive and maladaptive behavior (Reynolds & Kamphaus, 1992, 1998).

The Parent Rating Scales (PRS) of the BASC-2, which were employed in this study, are comprehensive measures of adaptive and problem behaviors (Reynolds & Kamphaus, 2004). Twelve syndrome scales are included on the PRS: Hyperactivity, Aggression, Conduct Problems, Anxiety, Depression, Somatization, Atypicality, Withdrawal, Attention Problems, Adaptability, Social Skills, and Leadership. Each scale yields a T-score with a mean of 50 and a standard deviation of 10. The scales were derived from factor-analytic methods (Reynolds & Kamphaus, 1992, 1998).

The first nine syndrome scales listed comprise the Clinical Profile. The syndrome scales designated as Hyperactivity, Aggression, and Conduct Problems are grouped under the

Externalizing Problem Composite Scale and the Anxiety, Depression, and Somatization syndrome scales are grouped under the Internalizing Problem Composite Scale. In addition to scale and composite scores, the BASC provides a broad composite score, the Behavior Symptom Index (BSI), which is composed of the following scales: Atypicality, Withdrawal, Attention Problems, Hyperactivity, Aggression, Depression. The BSI reflects the overall level of problem behaviors. The BSI is composed of those clinical scales that are shared by all age levels and that load highest on the general problem factor. A T-Score between 60 and 69 indicates the at-risk range and T-scores at or above 70 are in the clinically significant range for the scales and composites in the clinical profile (Reynolds & Kamphaus, 1992, 1998).

The Adaptive Profile is comprised of the scales designated as Adaptability, Social Skills, Leadership, Activities of Daily Living, and Functional Communication for the PRS. These scales also comprise the Adaptive Skills Composite. Unlike the clinical scales, lower scores on the Adaptive Profile reflect better functioning. A T-Score between 31 and 40 is in the at-risk range and T-scores below 30 are in the clinically significant range for the Adaptive Profile (Reynolds & Kamphaus, 1992, 1998).

The Executive Functioning scale was developed by Barringer and Reynolds (1995; Reynolds & Kamphaus, 2002) using an expert panel approach to identifying the BASC rating scale items for a frontal lobe and executive functioning scale. They surveyed editorial board members of the three leading clinical journals in neuropsychology, *Archives of Clinical Neuropsychology, Journal of Clinical and Experimental Neuropsychology,* and *The Clinical Neuropsychologist.* Each board member was asked to rate each BASC PRS item according to the strength of its perceived association with frontal lobe functioning. Based on the obtained ratings, the items were ranked and a series of item analyses were performed, using the BASC standardization and clinical norm groups. Then a set of 18 items with a high reliability (coefficient alpha of .84 on both the Parent Rating Scales-Child (PRS-C) and Parent Rating Scales-Adolescent (PRS-A) versions) was identified, 17 of which were common to the PRS-C and the PRS-A.

Reynolds and Kamphaus (2004) describe the content of the executive functioning scale as "The ability to control behavior by planning, anticipating, inhibiting, or maintaining goal-directed activity, and by reacting appropriately to environmental feedback in a purposeful, meaningful way." Sullivan and Riccio (2006) used data from a clinical sample of children and adolescents to determine the characteristics of the BASC Executive Functioning Scale. Their results indicated that the Executive Functioning Scale is useful in "identifying behaviors associated with executive dysfunction across disorders." Further, results of their correlational analysis indicated that scores on the BASC Executive Functioning Scale were significantly correlated with scores on *all* of the scales on the Behavior Rating Inventory of Executive Functioning (BRIEF) and the Conners' Parent Rating Scales Revised-Short Form (CPRS). The Executive Functioning Scale was refined in the BASC-2, resulting in a set of 10 scale items with a high reliability (see Table 2).

Table 2

BASC-2 PRS Items Associated With Frontal Lobe and Executive Functioning

PRS-C Item Number	PRS-A Item Number	Item
6	15	Cannot wait to take turns
26	70	Hits other children
N/A	71	Repeats one activity over and over [1]
N/A	13	Uses foul language [1]
36	97	Is a "self-starter" (reversed scoring)
73	136	Is easily distracted
10	82	Is easily upset
102	N/A	Interrupts others when they speak [2]
156	N/A	Changes moods quickly [2]
78	78	Adjusts well to changes in family plans (reversed scoring)
56	64	Argues when denied own way
116	20	Acts without thinking

1 PRS-C only
2 PRS-A only

The Executive Functioning Scale was used in comparisons of various clinical groups and showed high levels of discrimination. For example, the BASC normative sample had a mean T-score of 48.4 on this scale, whereas the BASC ADHD sample had a mean T-score of 64.00 (1.4 *SD*s above the total sample mean, and 1.56 *SD*s above the normal sample). Further, the BASC in general contains scales that directly assess some of the most common behavioral changes following TBI such as "disturbances of attention and concentration and disruption of the inhibitory systems of the brain" (Reynolds & Kamphaus, 2002). Scales that are influenced strongly by TBI, including problems of frontal lobe or executive functioning (e.g. Attention Problems, Learning Problems, and Conduct Problems scales) correlate significantly with some neuropsychological performance measures, such as the Wisconsin Card Sorting Test (Riccio et al., 1994). Moreover, the BASC Attention Problems scale was associated with the perseverative errors score, often considered the best measure of frontal lobe functioning on the Wisconsin Card Sorting Test (Reynolds & Kamphaus, 2002).

A recent study conducted by Garcia-Barrera, Kamphaus, and Bandalos (in press) examined the statistical and theoretical derivation of the BASC-2 for the estimation of executive functions in children. The original national standardization sample of the BASC–2 TRS for children ages 6 through 11 was used (N=2,165). Moderate-to-high internal consistency was obtained within each factor (.80 –.89). A panel of experts was used for content validity examination. A confirmatory factor analysis model with 25 items loading on 4 latent factors (behavioral control, emotional control, attentional control, and problem solving) was developed, and its statistical properties were examined. The multidimensional model demonstrated adequate fit, and it was deemed invariant after configural, metric, and scalar measurement invariance tests across sex and age. Given its strong psychometric properties, with further tests of item validity, this instrument was deemed useful for clinical and research purposes for the screening of executive functions in school-age children. Indeed, the BASC-2 Executive Functioning Scale was found to be a psychometrically and theoretically sound screening tool for executive functioning.

The Present Study

To review, the BASC-2 Executive Functioning Scale uses ratings of a child's behavior to measure dimensions that are reflective of aspects of executive functioning, fluid reasoning, planfulness, and attentional control. The studies reviewed above show a strong association between *Gf* and executive functioning that mirrors executive control processes and prefrontal functioning. Neuropsychological data connect executive control, goal management, *Gf* scores, and the disorganization of intelligent behavior following frontal lesions. The studies point to the hypothesis that poor executive functioning manifests as poor performance on fluid reasoning tasks and vice versa. Moreover, behavioral measures of executive functioning should be related to cognitive measures of fluid reasoning.

As there is a plausible rationale for using a behavioral measure to determine the external validity of a cognitive construct, it is reasonable to assume that the BASC-2 Executive Functioning Scale should correlate with cognitive measures of fluid reasoning (as research has shown fluid reasoning tasks are a good measure of executive functioning, as discussed previously) such as the WISC-IV PRI.

CHAPTER III

METHODOLOGY

Participants

The subjects were drawn from the database compiled at the Greater Essex County District School Board (GECDSB). The GECDSB evaluates children with a broad spectrum of disorders, although most are referred because they are exhibiting problems related to their academic performance, behavior, or both.

There were 931 children who received psychoeducational assessments at the GECDSB between September, 2006 and March, 2008. Of these children, 164 received both the WISC-IV and BASC-2 as part of their assessment. Children who were not fluent in English or who were on powerful medications (e.g., Risperdal, Haldol, Ativan) were excluded from the sample because the WISC-IV standardization sample also excluded participants who were not fluent in English or who were taking medication that might depress performance (e.g., antipsychotics, antidepressants, anxiolytics, anticonvulsants; Wechsler, 2003a). There were 152 children remaining (109 boys, 43 girls), ages 6 to16 years, who met the criteria for this study.

Data regarding the socio-economic status (SES) and ethnicity of the participants were not available. However, the Windsor area (as of 2001) reported ethnicity as 28.1% Canadian, 21.2% French, 18.5% English, 13.1% Irish, 12.1% Scottish, 9.7% Italian, 7.1% German, and 4.0% Polish (multiple responses included; Statistics Canada, 2001). Windsor's economy is primarily based on education, manufacturing, tourism, and government services. Table 3 presents available demographics of the current sample.

Table 3

Demographic Characteristics of Sample (n=152)

Variable	Number of Subjects	Percentage
	Sex	
Female	43	28.3
Male	109	71.7
	Age	
6-7	26	17.1
8-9	54	35.5
10-11	38	25.0
12-13	27	17.8
14-16	7	4.6

All data (i.e., participants, demographics, WISC-IV scores, and BASC-2 scores) were obtained by psychologists at the GECDSB. Informed consent was obtained from each parent prior to their child's assessment. The information used in this study was contained in an electronic database devoid of any personal information that might identify the participant. Access to the database was restricted to the primary researcher (Christine Purcell, M.A.), faculty supervisor (Joseph Casey, Ph.D.), and Supervisor of Psychological Services, GECDSB (Philip Ricciardi, Ph.D). All results are reported on a group basis and do not contain information that could be used to identify participants individually. This study was approved by the Research Ethics Board of the University as well as by the School Board.

Statistical Analyses

Taking the test publisher's view that the PRI of the WISC-IV places greater emphasis on fluid reasoning than similar Indexes on the previous editions of the WISC, it would be expected, based on the findings from the literature that there would be a significant correlation between the PRI and the Executive Functioning Scale of the BASC-2. However, studies by Keith et al. (2006) and Hale et al. (2008) raise the question whether the PRI is primarily a measure of fluid reasoning. If the PRI is not chiefly a measure of fluid reasoning, one would expect that the PRI would not be related to the Executive Functioning Scale of the BASC-2. Also, the PRI should not correlate significantly with conceptually unrelated measures on the BASC-2, such as the Somatization or Anxiety subtests.

In addition, it would be reasonable to expect that the Executive Functioning Scale of the BASC-2 would not correlate significantly with conceptually unrelated measures such as the Verbal Comprehension Index (VCI) of the WISC-IV, since the VCI is purported to be the best measure of crystallized intelligence, which is conceptualized as being vastly different from fluid reasoning (Sattler, 2001; Wechsler, 2003a). No predictions were made regarding the Working Memory Index (WMI) or Processing Speed Index (PSI) of the WISC-IV. However, one could make an argument based on descriptions of executive functioning and fluid reasoning, as well as theory surrounding an underlying construct of attentional control and Saggino et al.'s (2006) assertion that *Gf* loads on factors of memory span, that there could be a significant correlation between the Executive Functioning Scale of the BASC-2 and the WMI. Also, based on Sattler's definition of fluid reasoning as including mental efficiency reliant on processing speed and Saggino et al.'s assertion that *Gf* also loads on factors of intellectual speed, one could make the argument that there could be a correlation between the Executive Functioning Scale of the BASC-2 and the PSI. Whereas these analyses are not central to this study, they were undertaken for exploratory reasons and completeness.

A power analysis was conducted to determine the sample size required for correlational analyses to observe a small, medium, and large effect. The power of a statistical test is the probability that it will lead to the rejection of the null hypothesis (i.e., the probability that it will result in the conclusion that the phenomenon exists; Cohen, 1969). The power of a statistical test depends on three parameters: the significance criterion, the reliability of the sample results, and the effect size. The significance criterion is the probability of incorrectly rejecting the null hypothesis. The reliability of the results from the sample is the closeness with which it can be considered to represent the relevant population. The effect size is the degree to which the phenomenon is present in the relevant population or the degree to which the null hypothesis is false. In this study, the null hypothesis ijs that the PRI will have no relation to the Executive Functioning Scale of the BASC-2. Therefore, for the purposes of power analysis, it is hypothesized that the PRI will show a relationship with the Executive Functioning Scale of the BASC-2.

Four parameters of statistical inference are required to conduct a power analysis: power, significance criterion (a), sample size (n), and effect size (*ES*). They are related in that any one is a function of the other three. That is, when three are known and remain fixed, the other one can be determined (Cohen, 1969). When an investigator anticipates a certain *ES*, sets a significance criterion, and then specifies the amount of desired power, the n that is necessary to meet these specifications can be determined. Conventionally, when the investigator is conducting an exploratory study and has no basis for setting the desired power value, as in this study, the value .80 is used. Below, the required number of participants to see small, medium, and large effects are shown (see Table 4; when power = .80 and $a = .05$).

Table 4

Number of Participants Required For a Specific Effect Size

Effect Size		N
Small	.10	1571
	.20	393
	.30	175
	.40	99
Medium	.50	64
	.60	45
	.70	33
Large	.80	26
	1.00	17
	1.20	12
	1.40	9

This study included a sufficient number of participants to detect a small size effect (i.e., 152 participants), or a small amount of departure from the null hypothesis. The minimum number required to detect a small effect was found to be 99 participants. Although what constitutes a small, medium, or large effect size is somewhat arbitrary, overall, the larger this value is, the greater the degree to which the phenomenon under study must be manifested.

Several statistical methods were used to analyze the current data. First, it is necessary to establish whether the present test data on the WISC-IV—that is, data from a referred sample—has the same factor structure as the WISC-IV standardization sample. For the current study, it is also important to establish whether the subtests of the PRI load together in a referred sample. Thus, in keeping with the methods used in the WISC-IV standardization, a principal factor analysis with varimax rotation and a forced four-factor solution was conducted. In effect, factor analysis can be used for construct validation. If the PRI primarily measures a single construct in the current sample (which could be fluid reasoning or another unknown dimension), then subtests of the PRI should load on one factor (i.e., the PRI).

Next, to determine what the PRI measures it is important to look at external validity. Since fluid reasoning and executive functioning are conceptually similar, the PRI would have convergent construct validity if it correlated significantly with the BASC-2 Executive Functioning Scale and would support discriminant validity if it did not correlate highly (e.g., $\geq .45$) with a conceptually unrelated measure such as BASC-2 Somatization or Anxiety. Additionally, it was thought useful to group the Picture Concepts and Matrix Reasoning subtests together as the "best" measure of executive functioning as per Keith et al.'s (2006) findings indicating that these two subtests load on a "fluid reasoning" factor as well as to examine the Picture Concepts subtest alone as the "best" measure of executive functioning as suggested by Wechsler (2003a).

Finally, because the literature suggests there are behavioral differences in executive functioning as children mature, it was thought useful to look at a narrower age range. Data also suggest differences in fluid reasoning due to maturation of the prefrontal lobe. Further, in the WISC-IV standardization sample, for 6 and 7 year olds, the Picture Concepts subtest loaded on the VCI, not the PRI. So, to help minimize these developmental differences, the 6 and 7 year olds were removed from the sample (n = 126) and all previously mentioned analyses were performed again.

CHAPTER IV

RESULTS

Table 5 presents the means and standard deviations for the WISC-IV Index scores and core subtest variables for the referred sample. Since the supplemental subtests were not often administered by the GECDSB psychologists and were not included in the initial WISC-IV standardization factor analysis, it was thought that including these variables did not add valuable information to the current study. The means reported are slightly lower when compared to the standardization sample (for Index Standard Scores, M = 100, SD = 15; for subtest Scaled Scores, M = 10, SD = 3). Some variables showed kurtosis or skew when analyzed using univariate statistics. This is not unusual in a referred sample, where most children are experiencing academic difficulties and thus their Index scores tend to cluster below the mean, in the low average to average range.

Table 5

Means and Standard Deviations of the WISC-IV Indexes and Subtests in the Referred Sample

Index or Subtest	Index or Scaled Score Mean	Standard Deviation
VCI	92.56	14.90
PRI	94.71	15.00
WMI	85.74	14.59
PSI	86.72	9.72
Vocabulary	8.66	2.42
Similarities	8.96	2.87
Comprehension	8.59	2.56
Block Design	8.96	2.99
Picture Concepts	9.63	2.78
Matrix Reasoning	8.96	2.95
Digit Span	7.64	2.66
Letter-Number Sequencing	7.64	2.69
Coding	7.48	2.11
Symbol Search	7.99	2.40

Note N = 152

Table 6 presents the means and standard deviations for the BASC-2 variables for the referred sample. The T-scores reported are slightly higher when compared to the standardization sample (M = 50, SD = 10). Again, this is not uncommon with a referred sample, as some children may have behavioral difficulties which may or may not be related to their academic difficulties.

Table 6

Means and Standard Deviations of the BASC-2 Scales in the Referred Sample

Scale	T-Score Mean	Standard Deviation	Range of Scores
Executive Functioning	61.10	10.65	36-89
Somatization	62.19	17.40	42-120
Anxiety	83.53	17.53	48-120
Hyperactivity	58.04	9.84	4-86
Aggression	63.68	12.56	43-103
Conduct Problems	58.95	13.76	37-108
Depression	58.55	14.55	1-101
Atypicality	59.30	15.13	41-112
Withdrawal	55.74	14.80	34-105
Attention Problems	63.78	9.25	37-84
Adaptability	43.55	9.49	21-66
Social Skills	45.98	11.06	21-69
Leadership	44.71	10.10	22-75
Activities of Daily Living	40.87	10.38	11-70
Functional Communication	39.44	11.30	11-66
Externalizing Problems	58.96	13.56	33-93
Internalizing Problems	55.45	11.90	33-91
Behavioral Symptoms Index	60.19	14.44	5-99
Adaptive Skills	39.47	12.35	10-72

Note: N = 152

A principal factor analysis with varimax rotation and a forced four-factor solution was conducted on the current sample. The data showed the same four-factor solution as the WISC-IV standardization sample, where all ten core subtests of the WISC-IV loaded on their respective Indexes. That is, the Vocabulary, Comprehension, and Similarities subtests loaded on the Verbal Comprehension Index; Matrix Reasoning, Block Design, and Picture Concepts loaded on the Perceptual Reasoning Index; Coding and Symbol Search loaded on the Processing Speed Index; and Digit Span and Letter-Number Sequencing loaded on the Working Memory Index (see Table 7).

Table 7

Referred Sample Rotated Factor Matrix

	Factor			
WISC - IV Subtest (Scaled Score)	1	2	3	4
Similarities	**.686**	.209	.258	-.059
Vocabulary	**.890**	.149	.014	-.044
Comprehension	**.798**	-.022	-.030	.054
Block Design	.072	**.775**	.158	-.007
Picture Concepts	.102	**.358**	.343	.004
Matrix Reasoning	.184	**.684**	.279	.115
Digit Span	.040	.157	**.600**	.044
Letter-Number Sequencing	.049	.260	**.698**	.000
Coding	-.028	.086	.009	**.780**
Symbol Search	-.021	.337	.235	**.393**

Note Extraction Method Principal Axis Factoring Rotation Method Varimax with Kaiser Normalization

The factor analysis showed that the PRI accounts for 62.38 % of the variance of the PRI subtests. Table 8 shows that the factor loadings for the PRI subtests are moderate to high with respect to the PRI. These factor loadings were similar to the standardization data (see Table 8).

Thus, the results of the WISC-IV standardization factor analysis were replicated in the referred sample, although the loading of Picture Concepts onto the PRI was not as high as for the standardization sample.

Table 8

WISC-IV Standardization Sample and Referred Sample Factor Loadings for the PRI

	Referred Sample	Standardization Data
WISC-IV Picture Concepts	.36	.45
WISC-IV Matrix Reasoning	.68	.69
WISC-IV Block Design	.78	.66

Note. Extraction Method: Principal Axis Factoring

To test for convergent validity, the PRI should be correlated with the BASC-2 Executive Functioning Scale. To show discriminant validity, the PRI should not be correlated with other scales that should theoretically have no relation (e.g. BASC-2 Anxiety, BASC- 2 Somatization). The Bonferroni correction was used to address the problem of multiple comparisons. The PRI showed no significant correlation with the Executive Functioning Scale (r = -.06, $p > .50$). As expected, the PRI did not correlate significantly with the Anxiety (r = .09, $p > .10$) or Somatization Scales (r = .07, $p > .10$). In terms of the exploratory analyses, as expected, the Executive Functioning Scale did not correlate significantly with the VCI (r = -.07, $p > .10$). Moreover, the Executive Functioning Scale did not correlate significantly with the WMI (r = -.11, $p > .10$). However, the Executive Functioning Scale did correlate with the PSI (r = -.18, $p < .05$, effect size = .03).

Next, the Picture Concepts and Matrix Reasoning subtests were grouped together as the "best" measure of executive functioning as per Keith et al.'s (2006) findings indicating that these two subtests load on a “fluid reasoning” factor. This grouping of variables also showed no significant correlation with the Executive Functioning Scale (r = - .10, p > .10). This variable did not correlate significantly with the Anxiety (r = .15, p > .05) or Somatization Scales (r = .08, p >.10).

Finally, the Picture Concepts subtest was used as the "best" measure of executive functioning as suggested by Wechsler (2003a). The Picture Concepts subtest showed no significant correlation with the Executive Functioning Scale (r = -.06, p > .50). Further, Picture Concepts did not correlate significantly with either the Anxiety (r = .13, p > .10) or Somatization Scale (r = .04, p > .50).

To help minimize developmental differences, the 6 and 7 year olds were removed from the sample (n = 126). Very similar results were obtained. Tables 9 and 10 present the means and standard deviations for the 8 to 16 year old sample.

Table 9

Means and Standard Deviations of the WISC-IV Indexes and Subtests in the Referred Sample (8-16 year olds)

Index or Subtest	Index or Scaled Score Mean	Standard Deviation
VCI	93.32	13.60
PRI	94.67	15.34
WMI	85.85	14.51
PSI	85.97	9.16
Vocabulary	8.71	2.50
Similarities	9.03	2.89
Comprehension	8.64	2.59
Block Design	8.95	2.96
Picture Concepts	9.68	2.89
Matrix Reasoning	8.90	3.05
Digit Span	7.62	2.55
Letter-Number Sequencing	7.74	2.62
Coding	7.25	1.96
Symbol Search	7.97	2.29

Note N = 126

Table 10

Means and Standard Deviations of the BASC-2 Scales in the Referred Sample (8-16 year olds)

Scale	T-Score Mean	Standard Deviation	Range of Means
Executive Functioning	60.94	10.23	36-85
Somatization	63.24	17.90	43-120
Anxiety	84.19	17.32	48-110
Hyperactivity	58.32	10.19	4-86
Aggression	63.60	12.27	43-103
Conduct Problems	58.86	14.31	37-108
Depression	59.72	15.04	1-101
Atypicality	59.22	14.86	41-112
Withdrawal	56.55	15.18	35-105
Attention Problems	63.77	9.08	37-82
Adaptability	43.50	9.01	21-66
Social Skills	46.75	11.01	25-69
Leadership	44.63	9.65	22-70
Activities of Daily Living	39.99	12.44	11-70
Functional Communication	39.96	11.17	11-66
Externalizing Problems	59.44	13.42	36-93
Internalizing Problems	56.53	12.07	35-91
Behavioral Symptoms Index	60.61	14.74	5-99
Adaptive Skills	40.69	10.47	11-70

Note N = 126

The PRI showed no significant correlation with the Executive Functioning Scale (r = -.02, p > .50). As expected, the PRI did not correlate significantly with the Anxiety (r = .09, p > .10) or Somatization Scale (r = .07, p > .10). In terms of the exploratory analyses, as expected, the Executive Functioning Scale did not correlate significantly with the VCI (r = -.01, p > .50). Also, the Executive Functioning Scale did not correlate significantly with the WMI (r = -.18, p > .05). However, the Executive Functioning Scale did correlate with the PSI (r = -.22, p < .05, effect size = .05).

Again, the Picture Concepts and Matrix Reasoning subtests were grouped together as the "best" measure of executive functioning as per Keith et al.'s (2006) findings indicating that these two subtests load on the "fluid reasoning" factor. This grouping of variables also showed no correlation with the Executive Functioning Scale (r = - .08, p > .10). This variable did not correlate with either the Anxiety (r = .17, p > .05) or Somatization Scale (r = .10, p > .10).

Finally, the Picture Concepts subtest was used as the "best" measure of executive functioning as suggested by Wechsler (2003a). The Picture Concepts subtest showed no significant correlation with the Executive Functioning Scale (r = -.06, p > .50). Further, Picture Concepts did not correlate significantly with either the Anxiety (r = .17, p > .05) or Somatization Scale (r = .05, p > .50).

CHAPTER V

DISCUSSION

Fluid reasoning is a somewhat ill-defined psychometric construct that emerged based on the results of factor analytic studies (McCabe et al., 2010). Subsequent studies have shown fluid reasoning is associated with frontal lobe functioning (Kane et al., 2005). Because of its relationship with the frontal lobe, it is thought that fluid reasoning may be dimensional and overlap with executive functioning (Saggino et al., 2006). Fluid reasoning is assumed to be conceptually different from crystallized reasoning, in that is does not depend on previous learning (Sattler, 2001). In behavioral measures, individual differences in fluid reasoning are most obvious when attentional control is needed (Conway et al., 2002; Engle, Kane, et al., 1999). Thus, fluid reasoning and attentional control are considered related (Conway et al., 2002; Engle, Tuholski, et al., 1999).

The current study addressed the question of whether the PRI is a measure of fluid reasoning by comparing the PRI and the Executive Functioning Scale of the BASC-2 in a referred sample of children. The study sample comprised children referred for assessment due to chronic academic difficulties to determine if their difficulties in school were due to a learning disability, an intellectual disability, behavioral or emotional problems, or an attentional disorder. Less common would have been children referred because of a question of giftedness. Thus, there are few children in this sample who would be classified (for the purposes of research) as typical developmentally. Because this was a clinical sample, a check was performed to insure the factor structure was the same as that of the WISC-IV standardization sample and that conclusions drawn from this study can be generalized, which was found to be the case. Also in keeping with the WISC-IV standardization sample, the subtests of the PRI correlated most with one another, although Picture Concepts had a relatively weaker correlation with the PRI compared to the correlation between Picture Concepts and PRI in the normative sample. Given that this study did replicate the factor structure of the WISC-IV standardization sample, generalizations based on the present analyses regarding whether the PRI is a measure of fluid reasoning can be made.

In the present study, several, albeit related, measures of fluid reasoning were considered for analysis. First, the PRI showed no significant correlation with the Executive Functioning Scale. Further, the combination of the Picture Concepts and Matrix Reasoning subtests, which both loaded on Keith et al.'s (2006) fluid reasoning factor, showed no significant correlation with the Executive Functioning Scale. Finally, Picture Concepts, presented in the WISC-IV manual as the best measure of fluid reasoning (Wechsler, 2003a) also showed no significant correlation with the Executive Functioning Scale.

In terms of exploratory analyses, as expected the Executive Functioning Scale did not show a significant correlation with the VCI, which is typically describes as being conceptually different, since the VCI is thought to be a measure of crystallized intelligence, as opposed to fluid intelligence. The Executive Functioning Scale did not correlate with the WMI , but did, however, correlate with the PSI. Possible reasons for these correlations are discussed later in this section.

A number of possible explanations may be advanced to account for the absence of significant correlations found between the PRI and the Executive Functioning Scale. First, it may be that one of these measures is not reflecting fluid reasoning. In general, the BASC-2 is a well established tool supported by research (Reynolds & Kamphaus, 1992, 1998). Further, the BASC-2 Executive Functioning Scale was developed using an expert approach and this scale has been shown to correlate significantly with other behavioral measures of executive functioning such as the Behavior Rating Inventory of Executive Functioning (BRIEF; Sullivan & Riccio, 2006). Also, The Executive Functioning Scale distinguishes between various conditions, such as ADHD. Further, the BASC in general contains scales that directly assess some of the most common behavioral changes following TBI, including problems of frontal lobe or executive functioning that correlate significantly with some neuropsychological performance measures of frontal lobe functioning (Reynolds & Kamphaus, 2002).

On the other hand, the PRI has very little research and theory supporting the claim that it measures fluid reasoning. Given these considerations it would seem more likely that if one of these measures is not reflecting fluid reasoning it is more likely to be the PRI. Before this possibility is examined, some alternate explanations are presented.

First, the PRI and BASC-2 may measure different aspects of executive functioning. Several researchers (Stuss & Benson, 1984; Walsh, 1985) have stated that behavioral and cognitive measures of fluid reasoning/executive functioning may be measuring different concstructs. This may stem from fluid reasoning and executive functioning being ill-defined concepts that may reflect different dimensions of a broader, umbrella construct. That is, it may be that fluid reasoning and executive functioning tap different aspects of a multi-dimensional concept. In contrast with the body of research that has demonstrated both measures tap similar functions and likely share the same underlying construct, correlations across the behavioral and cognitive domains in these studies (Stuss & Benson, 1984; Walsh) identified few significant relationships. For example, Vriezen & Pigott (2002) examined the relationship between the BRIEF and individually-administered neuropsychological tests in children with traumatic brain injury. Forty-eight children with moderate to severe traumatic brain injury were administered the WISC-III and several performance-based tests of executive function (the Wisconsin Card Sorting Test, Trail Making Test Part B, verbal fluency), and a parent completed the BRIEF. Results indicated that the Metacognition Index from the BRIEF correlated with Verbal IQ, but none of the index scores from the BRIEF correlated with any of the performance-based tests of executive function.

These results may reflect a difference in behavioral and cognitive dimensions of fluid reasoning and executive function, and their specific neuroanatomical correlates (Stuss & Alexander, 2000). Some studies suggest that the dorsolateral prefrontal cortex is primarily involved with the cognitive aspects of executive function while orbito-frontal regions play an important role in emotional and social skills (Eslinger et al., 1997; Stuss & Alexander, 2000; Walsh, 1985). For example, performance on the Wisconsin Card Sorting Test (Heaton, 1981) was maximally impaired in patients with dorsolateral prefrontal lesions. (Stuss & Benson, 1984). In contrast, patients with orbito-frontal lesions showed no significant changes on intellectual tests, but did show changes in behavioral regulation (Stuss & Benson, 1984). Thus, some neuroanatomical studies support the dissociation of the cognitive and behavioral aspects of fluid reasoning.

A different interpretation, from a measurement perspective, might postulate that the items on the Executive Functioning Scale are more specific than the PRI subtests, aimed at reflecting particular behaviors that have been linked to frontal lobe functions (e.g., impulsivity, poor organization). In contrast, the PRI is more multi-determined (Anderson, 1998) requiring the integrity of a range of lower-order cognitive skills (e.g., visuo-spatial abilities, attention, motor co-ordination, and possibly verbal mediation). Research using tasks argued to provide 'purer' measures of executive functioning (e.g., the Controlled Oral Word Association Test, Anderson, Lajoie, & Bell, 1995; Tower of London, Shallice, 1982; as per Anderson, Levin, & Jacobs, 2002 and Garth, Anderson, & Wrennall, 1997) have found significant correlations between cognitive and behavioral measures.

Further, the sampling frame for the two types of data is different. For the BASC-2, parents are basing reports on their observations of the child's behavior in the 'real world', where the environment may be less predictable and structured than the quiet, one-to-one evaluation room, which is where the WISC-IV is administered. This context may mask a child's deficits in core elements of fluid reasoning/executive functioning including planning, attentional control, and flexibility, which may be clearly evident in day-to-day contexts such as home and school (Anderson, 2002). Conversely, perhaps a child may demonstrate adequate fluid reasoning on a standardized test, yet lack other skills required to successfully apply these reasoning skills to solve adaptive or social problems in the natural environment.

An alternative is that the PRI is still primarily a measure of perceptual organization, as in previous versions of the WISC. Studies suggest that Block Design is indeed primarily a measure of perceptual organization (e.g., Keith et al., 2006, Wechsler, 2003a). However, what research does exist does not support this notion, and the authors of the WISC state their intention to move toward fluid reasoning.

Another possibility, which may be especially likely in a pediatric population, is that the PRI is largely a measure of *g*. Measures of fluid intelligence have demonstrated substantial relations with performance on measures of general intelligence (Embretson, 1995; Engle, Kane, et al., 1999; Gustafsson, 1984, 1988; Kyllonen & Christal, 1990). Tests that directly measure fluid cognitive functions have higher *g* loadings than do other cognitive measures (Gustafsson, 1984, 1988). In particular, psychometric examinations of typically developing populations have found measures of fluid function to be essentially identical to general intelligence. Gustafsson (1988) went as far as to set *Gf* equal to *g*, spurring on Carroll (1996) to call for increased experimental work examining the identity of *Gf* relative to *g*. Psychometric evidence with more recent tests suggests that there is strong overlap between measures of fluid ability and *g*. Keith (2005) applied the technique of hierarchical confirmatory factor analysis to several data sets. For the Differential Ability Scales (Elliot, 1990), an intelligence test for children 2½ to 17 years of age, the fluid factor correlated .98 with *g* in one study and 1.0 in another. Kaufman and Kaufman (2004) applied Keith's confirmatory factor analysis approach to the Kaufman Assessment Battery for Children-Second Edition, for children 3 to 18 years of age. They observed 1.0 correlations between fluid cognition and *g*. Further evidence of the overlap between fluid reasoning and *g* comes from the WISC-IV standardization data, where Picture Concepts loads similarly on the VCI (.21) and PRI (.20) in children 6 to 7 years of age (Wechsler, 2003a). The VCI is thought conceptually different from the PRI, and one of its subtests, Vocabulary, has been found in some studies to have the highest *g* loading of all WISC-IV subtests (Wechsler, 2003a). Moreover, studies examining brain structures and neural interconnectivity show that fluid intelligence has a high degree of overlap with general intelligence (Duncan, Seitz, et al., 2000; Prabhakaran et al., 1997; Thompson et al., 2001). For example, as previously discussed, the study conducted by Duncan, et al. (2000) found that fluid intelligence derives from a specific frontal system important in the control of diverse forms of behavior. This study also put forward that, in contrast to the common view that *g* reflects a broad sample of major cognitive functions, high-*g* tasks do not show diffuse recruitment of multiple brain regions. Instead they are associated with selective recruitment of the lateral frontal cortex in one or both hemispheres. Despite very different task content in the three high-*g*-low-*g* contrasts in this study, lateral frontal recruitment was markedly similar in each case. That is, these frontal regions were recruited by a range of different cognitive demands. The results suggest that general intelligence and fluid intelligence recruit the same specific frontal system important in the control of diverse forms of behavior. These findings do not mean that fluid cognition and *g* are identical constructs. However, it may be difficult to separate the construct of fluid reasoning from the construct of general intelligence and on tests, particularly in children.

As Golden (1981) indicates, it is not until about ages 11 or 12, on average, that the "prefrontal areas of the brain that serve as the tertiary level of the output/planning unit develop" (p. 292). The identification of *Gf* factors in groups of normal children also has a distinct developmental component. These factors do not emerge as separate constructs until about age 6 or 7 (Elliot, 1990; Kaufman & Kaufman, 2004). Therefore, the relationship between *Gf* and *g* in children is likely to be a different phenomenon for children below age 6, for those between 7 and 11, and for adolescents (Elliot, 1990; Kaufman & Kaufman, 2004), a notion that is consistent with Piaget's stage theory of cognitive development. As most clinical measures of fluid reasoning/executive functioning have been originally designed for adult populations (including Matrix Reasoning), it may be that these tasks are tapping the area of general intelligence more than the domain of fluid reasoning in children whose prefrontal cortex has not yet fully developed. In children, the anterior brain regions, and the prefrontal cortex specifically, are dependent upon other cerebral areas for input, making it difficult to isolate the involvement of frontal regions from those of other developing cerebral areas in the expression of fluid reasoning/executive functioning (Anderson, 2002). Historically, it has been argued that fluid reasoning/executive functioning emerges only during late childhood and adolescence, and so plays a minor role in the behavioral features of brain dysfunction during early childhood (Anderson, 2002).

Cohen (1959) found in three groups of children (7 ½ years old, 10 ½ years old, and 13 ½ years old) about half of the total subtest variance on the WISC was shared in common and two-thirds of this communality (.35 of the total) was a function of *g*. Only .18 of the total variance reflected subtest specificity, while a considerably higher proportion (.28) lay in errors of measurement. Additionally, several more recent studies investigating the factor structure of the WISC-IV have found *g* to account for the greatest amount of variance (e.g., Watkins, 2006; Watkins, Wilson, Kotz, Carbone, & Babula, 2006). Bodin et al. (2009) in a study of 344 children (6-16 years of age) found that when they accounted for the indirect effects of *g*, the three PRI subtests had similar loadings on the Perceptual Reasoning factor. Clearly, a fuller picture of how behavioral and cognitive measures correlate in child neuropsychology is needed to determine whether fluid reasoning and general intelligence are essentially the same construct in children.

Finally, while the revisions to the WISC-IV PRI were intended to bolster the representation of fluid reasoning, these well-intentioned modifications may have removed components of fluid reasoning already present in previous versions. For example, mental efficiency is considered a component of fluid reasoning (Howieson & Lezak, 2002, Sattler, 2001). By removing processing speed it is less likely mental efficiency is being measured. Further, the current study found the only significant relationship was between the Executive

Functioning Scale and the Processing Speed Index, suggesting mental efficiency may indeed be an important part of fluid reasoning.

Additionally, there is evidence the newly added Picture Concepts subtest may invoke verbal mediation (Wechsler, 2003a, p. 50). Further, by removing processing speed from the PRI, when the answer is not immediate, the test taker may invoke verbal mediation simply because they have the time to do it. Certainly, it is important to consider not only what has been added to the latest version to the PRI, but also what has been removed.

The results of this study suggest that the PRI measures something other than fluid reasoning, at least to the extent that fluid reasoning involves inhibition and attentional control as emphasized, in this study, by the Executive Functioning Scale. However, this result is not necessarily grounds to conclude that the PRI is not measuring some other specific cognitive process such as abstract reasoning or novel problem-solving that may not significantly overlap with attention control.

Limitations and Future Research Directions

Interpretation of the results of the current study should be made in the context of its limitations. First, it may be that not enough children in the current sample are exhibiting problems with executive functioning to produce significant results. That is, there may be an insufficient range of scores on the Executive Functioning Scale. In fact, of the scores of the 152 children that make up this sample, 83 scores were in the normal range on the Executive Functioning Scale, whereas 43 scores were in the at-risk range, and only 26 scores were in the clinical range. A consideration for future studies would be to use a sample with a wider range of scores on the Executive Functioning Scale. Certain populations that are more likely to have problems with executive functioning, such as TBI and ADHD, would likely include more cases in the at-risk and clinically significant range. Put another way, perhaps there are not a sufficient number of children with pathological levels of executive functioning to demonstrate a relationship between the PRI and the Executive Functioning Scale.

Another limitation of this study is with the measures themselves. It would have been preferable to include other tests of fluid reasoning to determine whether the PRI correlates with measures known to tap fluid reasoning. For example, the Wisconsin Card Sorting Test (Heaton, 1981) and the Children's Category Test (Boll, 1993) are tasks shown to measure problem-solving independent of formal learning (e.g., mathematics; Boll, 1993; Heaton, 1981). It would be interesting to see how these measures correlate with the PRI in order to further investigate whether the PRI measures fluid reasoning. Indeed, measures such as the Wisconsin Card Sorting Test, the Children's Category Test, and other neuropsychological measures of problem-solving could be used in future research to help determine the underlying constructs of the PRI. It is particularly important to examine several measures of executive functioning with child populations as the overlap between aspects of executive functioning and other cognitive domains can confound conclusions based on clinical evaluations (Baron, 2004). Baron gives several examples of why it is essential to use a variety of test instruments to avoid cognitive confounds:

> a broad executive functioning deficit might be invoked to explain task difficulty, but since a degree of attentional control is necessary for any successful task performance, the equally plausible alternative hypothesis of specific attentional disorder might be more accurate. A degradation of semantic or phonological memory could explain a semantic or phonemic word fluency deficit...Information processing speed might be the

> component of principal interest for executive functioning tests such as word or design fluency. Attentional aspects of executive functioning might play a crucial role in the assessment of working memory while other executive functioning components such as abstraction, problem-solving, and planning, have only a minimal relationship with memory processes...Active hypothesis testing during evaluation is essential in order to arrive at the most salient possibility.

Given that the current study data was derived from psychoeducational assessments, there was a limited range of tests available for analysis relative to what would be available from a comprehensive neuropsychological assessment. Consequently, other measures of fluid reasoning were not available for analysis.

This study demonstrates the need for additional investigations that explore further what the PRI measures. Studies that look at the relationship between the PRI and other higher-order cognitive tests, which ordinarily could be achieved in the context of a comprehensive neuropsychological battery, would be a useful direction for future research. The results of this study suggest that practitioners consider interpreting the PRI in the context of other cognitive and behavioral tests of fluid reasoning and executive functioning and that it is likely not good practice to interpret the PRI in isolation as reflective of fluid reasoning.

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Appendix

Standardization, Reliability, and Validity of the Measures

The WISC-IV

Standardization

Consistent with previous WISC versions, the WISC-IV was standardized on a population of 2200 children ages 6-16, stratified on the basis of contemporary census data with regard to age, sex, race, level of parental education, and geographic region. In keeping with previous standardization procedures, for purposes of reliability and validity evaluations, the standardization sample was divided into eleven age groups, each comprising 200 children (100 girls and 100 boys; Wechsler, 2003c; Williams et al., 2003).

Reliability and Validity

As expected, the WISC-IV is considered to be a psychometrically sound instrument (Kaufman et al., 2006; Sattler & Dumont, 2004). The average split-half internal consistency coefficients for the standardization sample are .97 (FSIQ), .94 (PRI), .92 (WMI, and .88 (PSI; Wechsler, 2003c); all of which are equal to or greater than the consistency values reported for the corresponding scales on the WISC-III (Williams et al., 2003). Similar to previous WISC editions, consistency estimates for the individual subtests are somewhat lower than those associated with composite scales, with median reliability values ranging from .79 (Symbol Search and Cancellation) to .90 (Letter Number Sequencing; Kaufman et al., 2006, Wechsler, 2003c, Williams et al., 2003). Thus, the Full Scale and Index scale reliabilities for the entire age range are described as high, while the majority of individual subtest reliabilities are considered to be moderate (Kaufman et al., 2006, Sattler & Dumont, 2004). Demonstrating the internal consistency of the WISC-IV Full Scale and Index scores across various populations, reliability coefficients for 16 clinical groups met or exceeded those reported for the standardization sample (Wechsler, 2003c).

In addition to being reliable, the WISC-IV is also considered to be stable (Wechsler, 2003a). Similar to its predecessors, WISC-IV test-retest stability coefficients for the Full Scale and Index scores range from excellent (>.90; VCI and FSIQ) to good (>.80: PRI; WMI; PSI). At the subtest level, average stability coefficients range from excellent (.92; Vocabulary) to adequate (.76; Picture Concepts; Sattler & Dumont, 2004; Wechsler, 2003c).

In keeping with the Wechsler tradition, the criterion validity of the WISC-IV was evaluated by examining the relationship between this revised test and other instruments assumed to measure similar constructs (Kaufman et al., 2006). According to the test developers, the WISC-IV FSIQ and Index scores correlated significantly with analogous scores from the WPPSI-III, WAIS-III, WASI (Wechsler, 1999), and WIAT-II. Similar studies conducted on populations outside of the standardization sample support these findings (Edwards & Paulin, 2007). Pertinent correlation patterns between WISC-IV scores and corresponding scores from the Children's Memory Scale (Cohen, 1997), BarOn Emotional Quotient Inventory (BarOn EQ; Bar-On & Parker, 2000), Gifted Rating Scale (GRS; Pfeiffer & Jarosewich, 2003), and Adaptive Behavior Assessment System – Second Edition (ABAS-II; Harrison & Oakland, 2003) have also been reported (Wechsler, 2003c).

The construct validity of the WISC-IV was evaluated by the test developers through the examination of composite and subtest score intercorrelations, as well as exploratory and confirmatory factor analyses (Wechsler, 2003c). With respect to intercorrelation research, as predicted, all WISC-IV Indexes are significantly correlated, providing empirical support for the FSIQ. Similarly, demonstrating the validity of the Verbal Comprehension, Working

Memory, and Processing Speed Scales, subtests within each of these Indexes correlate more highly with each other than with subtests associated with other scales (Wechsler, 2003c). In contrast, subtests composing the PRI correlate almost as highly with subtests on the VCI as with subtests within the same scale; a finding that again calls into question the precise constructs measured by the PRI (Baron, 2005).

The BASC-2

Standardization

Standardization of the BASC-2 took place from August 2002 to May 2004. The General norm (i.e., non-clinical) samples included a total of more than 13,000 TRS, PRS, and Self-Report cases from the ages of 2 through 18 years. The overall standardization sample came from over 375 sites in 257 cities and 40 states. Children were sampled from various settings, including public schools, private schools, mental health clinics and hospitals, clinics, and other facilities. The sample was designed to resemble the United States population with respect to sex, socioeconomic status (as indicated by parental education), race/ethnicity, geographic region, and classification in special-education or gifted programs.

Reliability and Validity

TRS. Internal-consistency reliabilities of the BASC-2 TRS composites and scales are high and quite consistent between males and females, between clinical and nonclinical groups, and at different age levels. For the General norm samples, composite score reliabilities are very high: in the middle .90s for the Behavioral Symptom Index and Externalizing Problems composite, in the low to middle .90s form the School Problems and Adaptive Skills composites, and in the high .80s to low .90s for the Internalizing Problems composite.

In terms of test-retest reliability, a sample of children (i.e., the same child) was rated twice over an interval of 8 to 65 days between ratings. Test-retest reliabilities for the composite scales were in the middle .80s to the low .90s except for Internalizing Problems on the adolescent level (.78). The test-retest reliabilities for the Adaptability Scale ranged from .78 to .86.

An interrater reliability study was done at each age level of the TRS. Each child included in the study was rated by two different teachers with a period of 0 to 62 days between ratings. In terms of construct validity, the adaptive scales had higher correlations with one another than the clinical scales did.

In terms of criterion validity, the BASC-2 TRS was evaluated by examining the relationship between other instruments assumed to measure similar constructs. According to the test developers, the BASC-2 composites and scales correlated very highly with composites and scales that measure the same constructs on the Achenbach System of Empirically Based Assessment (ASEBA) Caregiver-Teacher Report Form. Correlations between the clinical scores range from .78 to .81, and correlations between the Externalizing Problems scores range from .75 to .85. The Internalizing Problems correlations were more variable, ranging from .64 to .80. Correlations between scales that measure similar constructs on the BASC-2 TRS and the Conners' Teacher Rating Scale-Revised were generally moderately to highly correlated, with the exception of the BASC-2 Anxiety scale and the Conners' Anxious-Shy scale (ranging from .26 to .35).

PRS. Internal-consistency reliabilities of the BASC-2 PRS composites and scales are high and quite consistent between males and females, between clinical and nonclinical groups, and at different age levels. For the General norm samples, composite score reliabilities are high: in the low to middle .90s for Adaptive Skills and the Behavioral Symptoms Index, and in the middle .80s to middle .90s for Externalizing Problems and Internalizing Problems. Reliabilities for Externalizing Problems and Internalizing Problems tended to be slightly higher at the child and adolescent levels (from .89 to .95) than at the preschool level (from .85 to .91). Reliabilities of the individual scales are also high, although slightly lower than the TRS. The median values range from .80 to .83 at the preschool level, from .83 to .87 at the child level, and from .83 to .86 at the adolescent level. Reliabilities of the individual scales are also high.

In terms of test-retest reliability, a sample of children (i.e., the same child) was rated twice over an interval of 9 to 70 days between ratings. Test-retest reliabilities for the composite scales were in the low .80s to the low .90s except for Internalizing Problems on the child level (.78).

An interrater reliability study was done at each age level of the PRS. Each child included in the study was rated by two different parents/caregivers with a period of 0 to 70 days between ratings. In terms of construct validity, the adaptive scales had higher correlations with one another than the clinical scales did.

In terms of criterion validity, the BASC-2 PRS was evaluated by examining the relationship between other instruments assumed to measure similar constructs. According to the test developers, the BASC-2 composites and scales correlated very highly with composites and scales that measure the same constructs on the Achenbach System of Empirically Based Assessment (ASEBA) Child Behavior Checklist. Correlations between the clinical scores range from .73 to .84 and correlations between the Externalizing Problems scores range from .74 to .83. The Internalizing Problems correlations were more variable, ranging from .65 to .75. Correlations between scales that measure similar constructs on the BASC-2 PRS and the Behavior Rating Inventory of Executive Functioning (BRIEF) were generally moderately to highly correlated.

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